

HARBOUR IMPROVEMENT
ON THE
PACIFIC COAST OF THE
UNITED STATES.

BY
WILLIAM WRIGHT HARTS,
MAJOR, CORPS OF ENGINEERS, U.S. ARMY, ASSOC. INST. C.E.

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Geology

was a question for many years whether the rock thus placed would not ultimately sink into the sand, causing settlement of the jetty and perhaps its ultimate destruction. In the effort to avoid this, use was made of mattresses composed of brush fascines bound together while slung under the tramway and then sunk in place with rock ballast by slacking off the supporting ropes. Upon this the rock was then dumped, the mattress serving to cut off all currents underneath and thus permit the accretion of sand, which quickly collected in the angle of the jetty. This brush mattress foundation has now been abandoned, except at the shore ends where wave-action is severe, in favour of a mattress of spalls and fine rock, which has been found efficacious at several places.

This general method of jetty-construction was first undertaken at Yaquina Bay, which is the pioneer work of this character on the Pacific Coast. The locality was a suitable one to begin upon, as the expense would not have been extreme in case of failure, and the prospect of arriving at a satisfactory solution appeared promising. The success of the work justified the adoption of this method of improvement elsewhere, and it has now been applied at Gray's Harbour, the mouth of the Columbia River, Coos Bay, the mouth of Coquille River, and Humboldt Bay, and has been suggested for several other localities.

MOUTH OF THE COLUMBIA RIVER.

The Columbia River is the largest and most important stream on the Pacific Coast of the United States. It rises in the mountain lakes of British Columbia, flows in a southerly direction and then westward, and empties into the ocean between the States of Washington and Oregon. It is confined between permanent banks down to within about 5 miles of its mouth, where it broadens to a width of $3\frac{1}{2}$ miles; the estuary having several channels which are more or less permanent. The mouth lies between a high rocky headland on the north, known as Cape Disappointment, and a long, low sand spit on the south, called Point Adams. In its upper portions the river has worn its channel through rock, thereby supplying immense quantities of sand; so that in passing downstream, as the slope becomes more moderate, sand bars and sand islands occur in increasing numbers. These islands are constantly changing; wearing away at their heads and building out at their downstream ends.

About the mouth of the river there are many spits, bars, and shoals within and without the entrance. These are composed of fine, easily transported sand, readily agitated in the almost incessant

surf about the entrance, and easily shifted in the currents set up by the wind and tide. At the gorge, where the currents are confined to a width of about 3 miles, depths of 60 feet and 70 feet are found; and from this point there have been occasionally, for example in 1839 and 1874, as many as three channels, diminishing in depth seaward and variable in direction, location, and depth (Figs. 1 and 2, Plate 6). The entrance is encircled by the usual bar, which lies about 3 miles at sea and has channel depths varying from time to time within the limits of 10 feet and 25 feet; the entire length of the bar, measured along its crest, being from 10 miles to 12 miles. From Point Adams southward there is a continuous beach 23 miles long, composed mainly of the same fine grey sand. On the north side of the entrance there are also shoals, spits, and sand islands, which were formerly constantly shifting, like the others, in a fairly regular cycle of change.

The fresh-water discharge of the river at low stages has been estimated to be from 90,000 to 120,000 cubic feet per second, and at times of great freshets it is probably between 1 million and $1\frac{1}{2}$ million cubic feet per second. This flow causes a strong predominance in favour of the ebb current. The high waters are caused by the combined influence of warm rains and melting snows in the mountain ranges, and are believed to carry to the sea large quantities of the fine sand which exists in such profusion along the upper portions of the stream. The Columbia is not ordinarily considered a sediment-bearing stream, being fairly clear at ordinary stages; but after examining the bottom contours about the entrance it seems undeniable that most of the moving sand has been so transported, although the erosion of the headlands and the attrition of the cobbles and shingle along the shores of the ocean have formed an important source.

The average tidal outflow is estimated at 1,200,000 cubic feet per second on a mean tide of 7.4 feet, and at $1\frac{1}{2}$ million cubic feet per second on maximum tides of 9.5 feet. The maximum rate of the ebb on these tides may be roughly estimated at 2,400,000 and 3 million cubic feet per second, respectively. The currents seaward are very strong off Point Adams, a velocity as high as $4\frac{1}{2}$ knots having been recorded, and 6 knots having been reported by pilots. The ebb currents have been noticed as far as 150 miles at sea.

The lower portion of the bay is an estuary having an area of about 140 square miles. The depths over the bar, before improvement, varied between 15 feet and 18 feet, increasing occasionally to 25 feet and 27 feet as the channel shifted to the most favourable location (Figs. 1 and 2). The general trend of the sand

drift has been noticeably northward, the tendency being to prolong the beach lying south of Point Adams toward the northwest in a long spit known as Clatsop Spit. This drift has always created a pressure on the entrance channels, crowding it gradually to the northward. When the natural channel direction was south-west from the deep water inside of Point Adams the depths in the main channel over the bar were best. But there usually existed at such times a swash channel to the north, over Peacock Spit, which carried part of the discharge and was separated from the main channel by large middle-ground shoals called the "middle sands." (See Fig. 2 for partial illustration.) As the pressure on the channel while in this best location increased in the course of time, due to the drift from the south, the main channel swung northward, scouring off the southerly edge of the middle sands and finally closing the north swash channel, probably with the sand thus gathered. A portion of this mid-ground shoal extended above low water, forming an island known as Sand Island, the presence of which in its most southerly location indicated that the best conditions of outlet depths over the bar were to be expected. As the channel swung northward, this island also moved northward, finally attaching itself to Peacock Spit at the end of Cape Disappointment. At the same time the depths in the main channel grew less, and its navigability and reliability diminished steadily. By the time the main channel had reached its most northerly location a new swash channel was forming around the end of Point Adams, which in time grew deeper until in its turn it became the main channel, permitting the growth of a new Sand Island, and thus commencing a new cycle of change like that already described.

In 1882 plans were adopted for the improvement of this entrance by the construction of a jetty about $4\frac{1}{2}$ miles long, running northwesterly from Point Adams toward Cape Disappointment, with a view to confine the outflow sufficiently to extend the scouring action of the ebbs through the bar into deep water, and thus produce an outlet having a depth of 30 feet (Fig. 3, Plate 6). As soon as the jetty had been extended across the shoals the northward movement of the channel ceased. While the area in the angle of the jetty was filling the channel remained stationary, and it was not until 1895, when the sand wave overlapped the jetty, that it began again to show indications of a tendency to swing farther northward. This action, however, ceased in 1899.

The plans of the engineers contemplated a jetty 12 feet above mean lower low water at the inner end, sloping to 10 feet above this

datum in a distance of 1.8 miles and to 4 feet above this datum at the outer end, the estimated cost being £742,000. The work was completed in 1896 at a cost of less than £400,000, and appeared at that time to be entirely successful. It had, at a little more than one-half of the estimated cost, accomplished the projected results, a channel having been secured that afforded a 30-foot depth over the bar (Fig. 4, Plate 6). In 1896 the depth was 31 feet at the mean of the lower low waters.

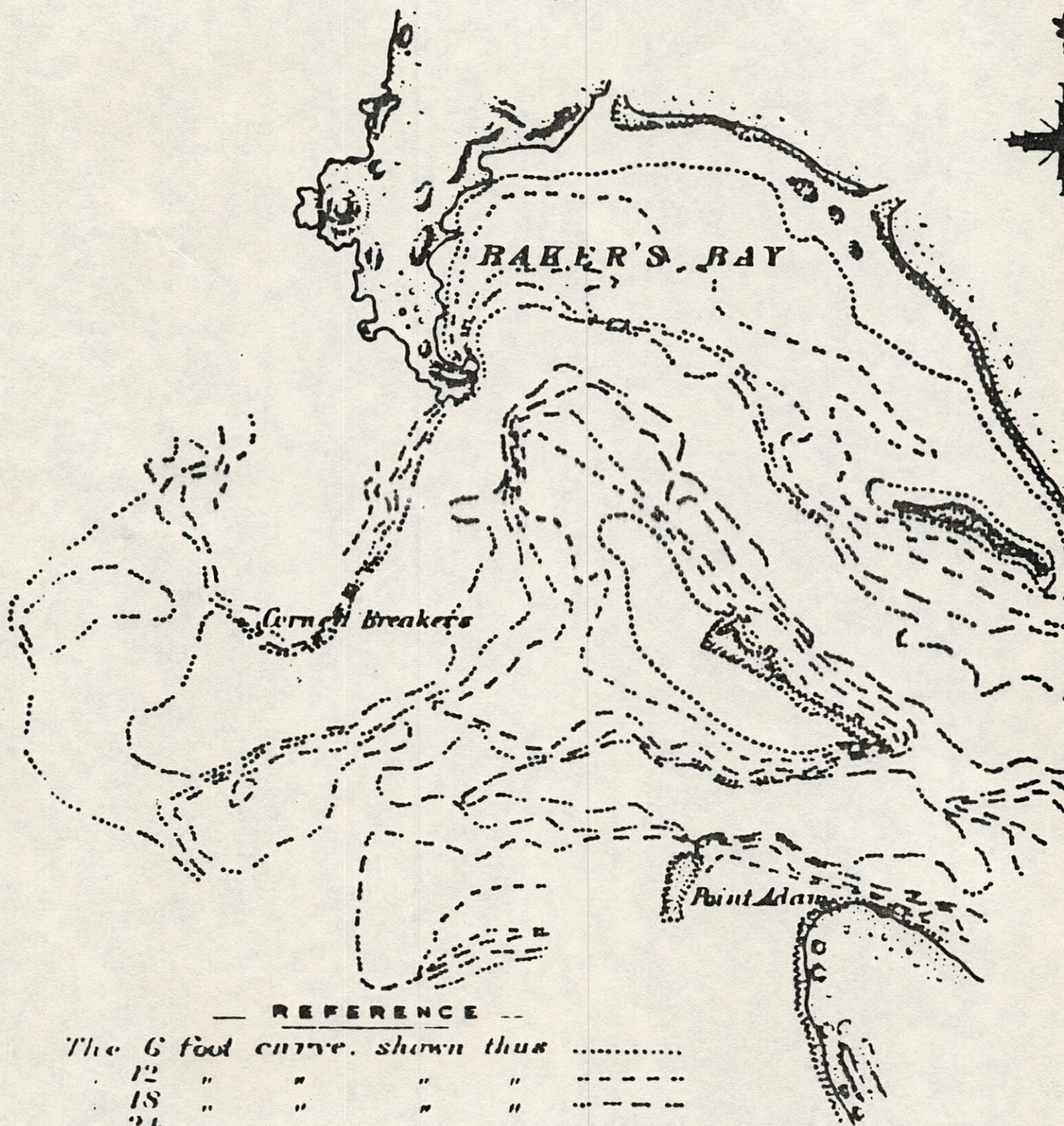
The reported completion of the work, however, proved to be premature; the length and height of the jetty not being sufficient to provide for the future maintenance of the favourable depths that had been obtained. Shoaling commenced, and by 1898 the depth had been reduced to 28 feet and the channel had shifted northward into an unstable location. By 1902 the shoaling had progressed to such an extent that there were several channels over the bar, the best showing only 21 feet (Fig. 5).

In view of this deterioration the project for improvement was modified in 1899, and plans were prepared with a view to a permanent increase of channel-depth to 40 feet. These plans, which are now being executed, contemplate an extension of the jetty $2\frac{1}{2}$ miles farther seaward, the entire work to be brought up to mid-tide level; this elevation having been adopted mainly on grounds of economy, since a higher general level than this could not be maintained without constant expense. The new project provides also for a north jetty, to be built out from Cape Disappointment over Peacock Spit in case the south jetty should fail to give the expected depth of 40 feet unaided. The distance between the outer ends of the two jetties is laid down as 2 miles (Fig. 6). This width is based upon the need of flat slopes for the accumulations of sand which extend along the sides of the jetties, and which, rather than the rock wall itself, act as the immediate agency in directing the currents.

The cost of the new work has been estimated at £502,000 for the south jetty and £245,000 for the north jetty; making a total of £747,000, which includes £50,000 for a dredger to assist in hastening the scour. Already the new work, which has extended the old jetty about a mile (making it approximately $5\frac{1}{2}$ miles long altogether), has had the effect of combining the several channels into one about 6,000 feet wide, and of increasing the depth to 25.5 feet (Fig. 6). The results of the new work will be watched with interest as the construction progresses, and there seems to be little doubt that its completion will fulfil the requirements of the project.

Fig: 1.

PACIFIC OCEAN

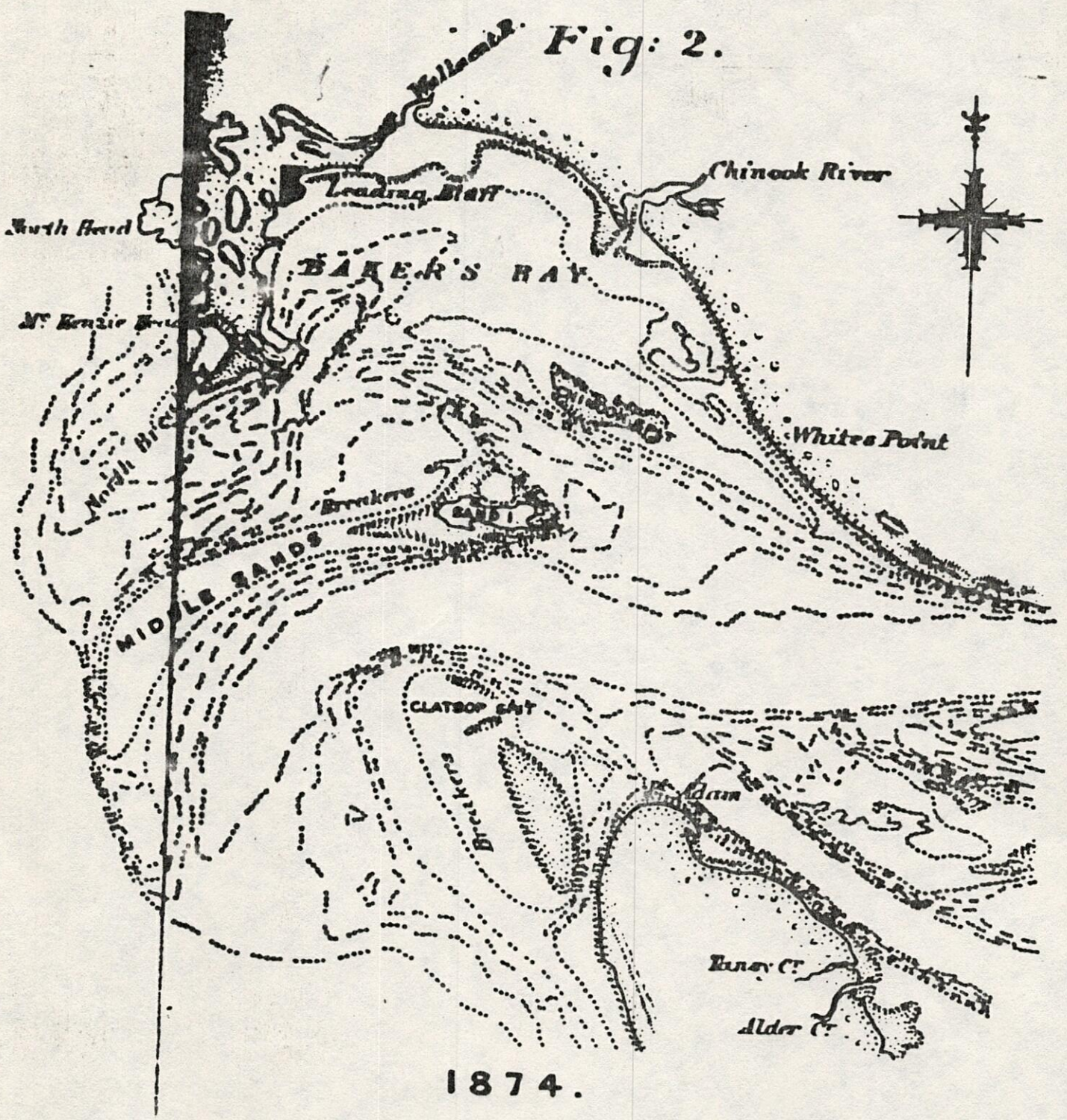


— REFERENCE —

The 6 foot curve, shown thus	
12 "	-----
18 "	-----
24 "	-----
30 "	-----

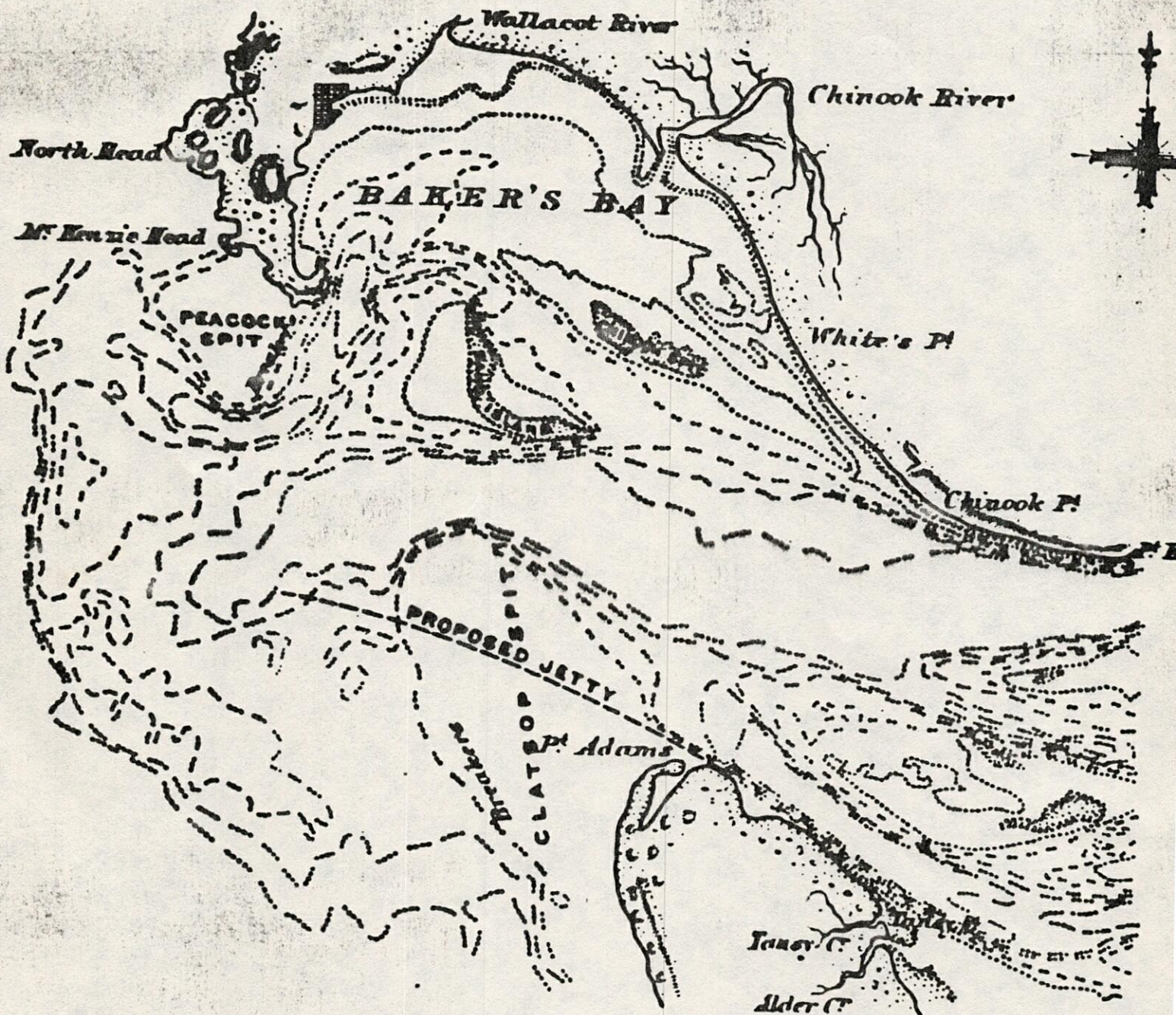
1839.

Fig: 2.



Mile 1 4 0 1 2 3 Fig

Fig. 3.



1881.

Mile 1 1/2 0 1 2 3
Fig^s 3

Fig: 4.

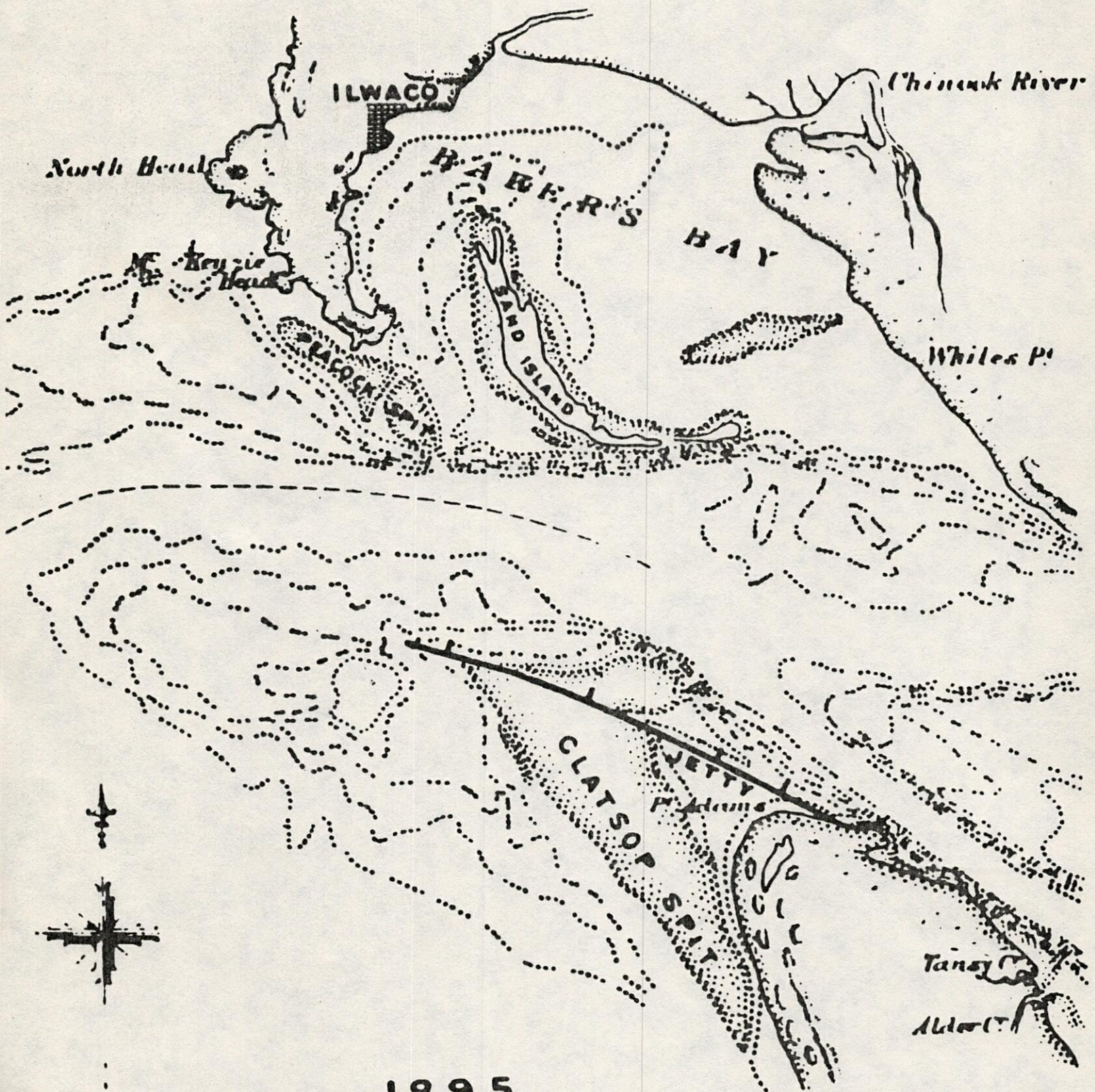
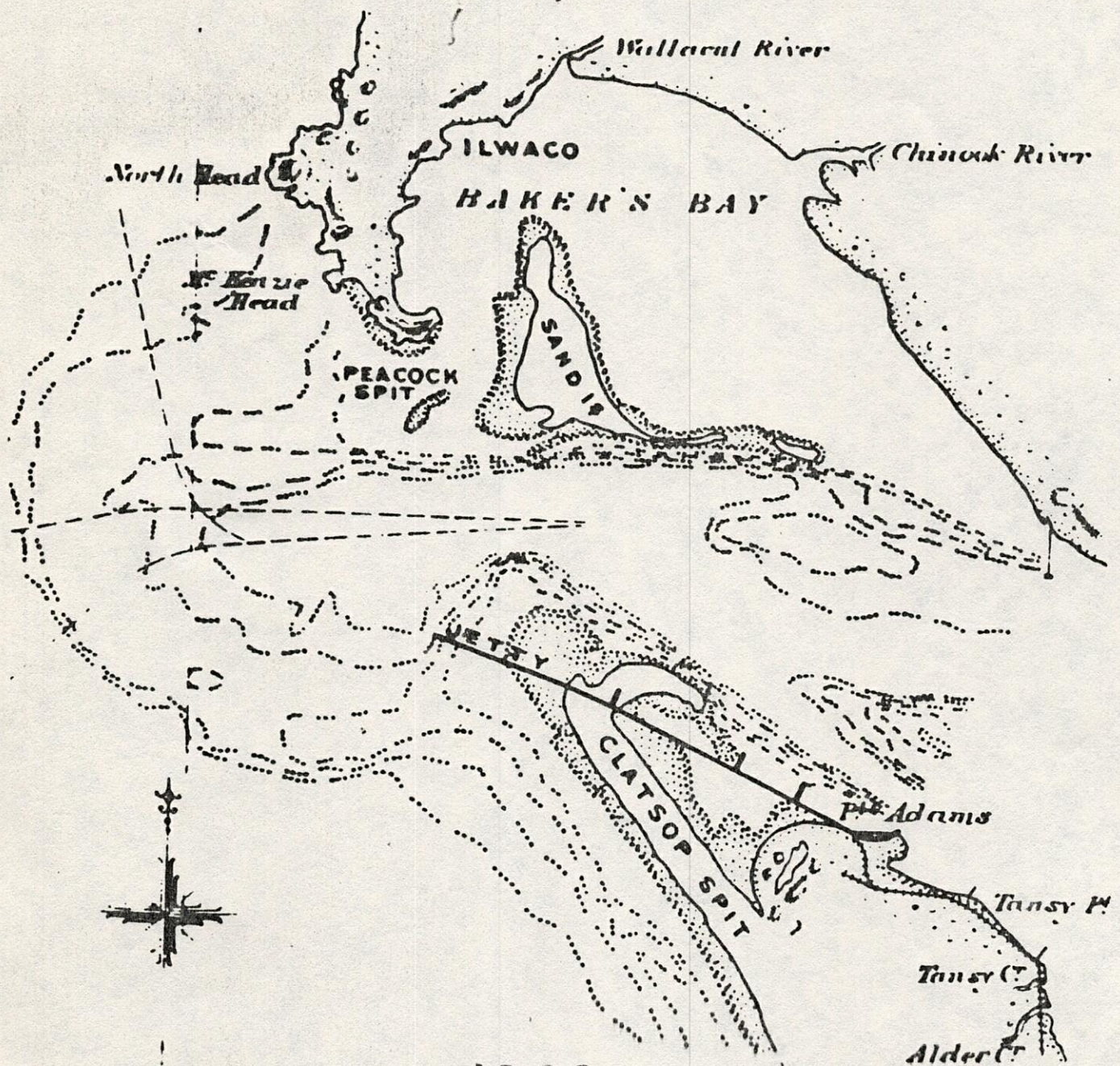


Fig. 5.

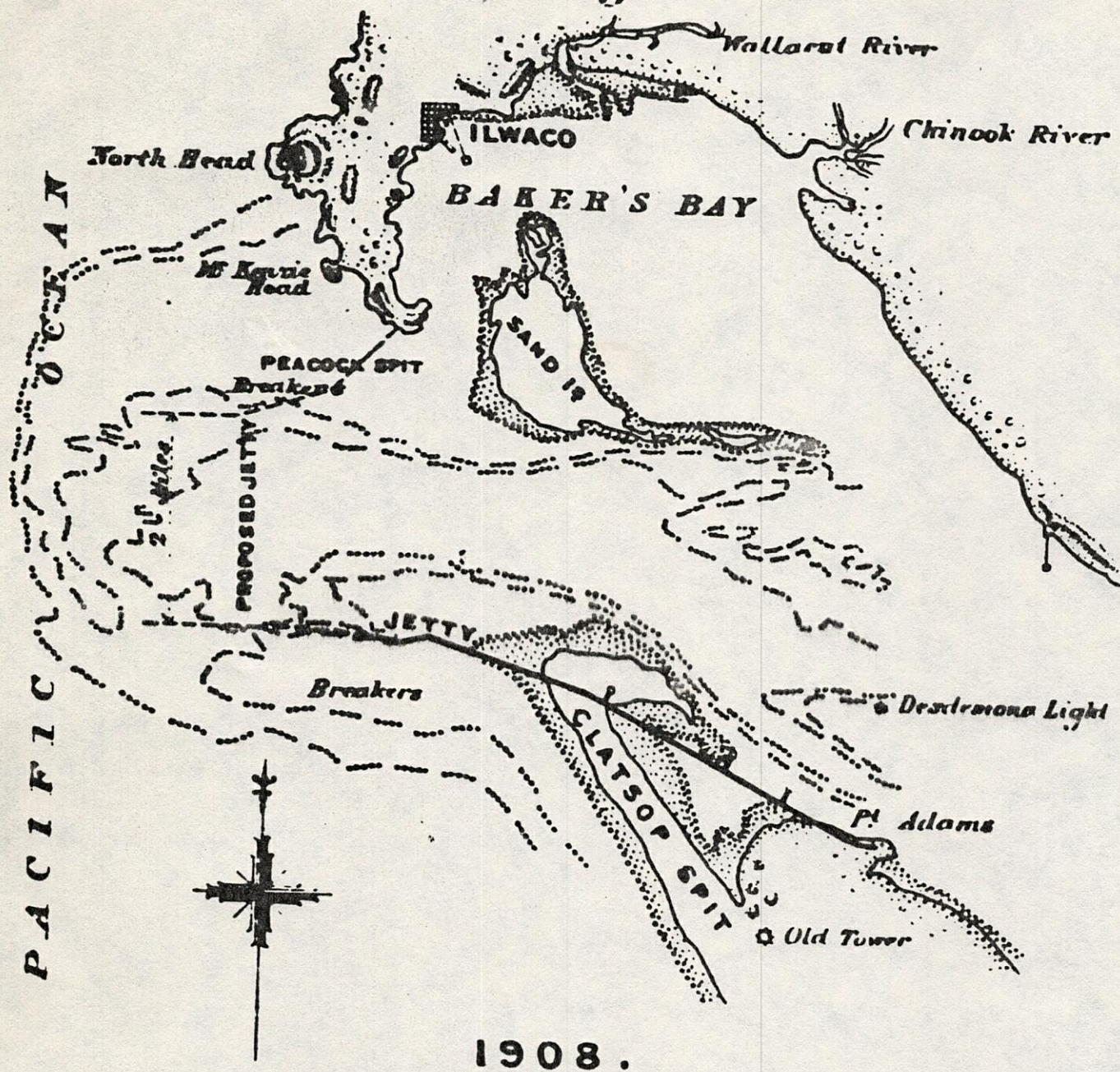


1902.

Mile 1 1/2 0 1 2

Fig. 5

Fig: 6.



Mile 1 1/2 0 1 2 3

Fig^s